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# Growth, puberty, and carcass characteristics of Brahman-, Senepol-, and Tuli-sired F<sub>1</sub> Angus bulls<sup>1,2,3</sup>

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**ABSTRACT:** Postweaning growth, sexual development, libido, and carcass data were collected from two consecutive calf crops using 31 Brahman × Angus (B × A), 41 Senepol × Angus (S × A), and 38 Tuli × Angus (T × A) F<sub>1</sub> bulls. Following weaning (by mid-September) and preconditioning, at the start of the study (late September) bulls were fed concentrate (three times each week at a rate equivalent to 4.5 kg/d) on bahiagrass pasture for approximately 250 d. At the start of the study and at 28-d intervals, BW, hip height, and scrotal circumference (SC) were measured. Concurrently at 28-d intervals, when the SC of a bull was ≥ 23 cm, semen collection was attempted using electroejaculation. Ejaculates were evaluated for presence of first spermatozoa (FS), 50 × 10<sup>6</sup> sperm with at least 10% motility (PU), and 500 × 10<sup>6</sup> sperm with at least 50% motility (PP). After all bulls reached PP they were subjected to two libido tests. Carcass data were collected on all bulls (n = 110) and Warner-Bratzler shear (WBS) force values were assessed on a subset (n = 80). For both years, B × A bulls were heavier ( $P < 0.05$ ) and taller ( $P < 0.05$ ) than S × A and T × A bulls at the start and end of the study. However, breed type did not influence ( $P > 0.10$ )

gain in BW or hip height during the study. Scrotal circumference of T × A bulls was larger ( $P < 0.05$ ) than that of B × A or S × A bulls at the start of the study, but there was no effect ( $P > 0.10$ ) of breed type by the end of the study. At PU and PP, B × A bulls were older ( $P < 0.05$ ), heavier ( $P < 0.05$ ), and taller ( $P < 0.05$ ) and had larger ( $P < 0.05$ ) SC than S × A and T × A bulls. Tuli × Angus bulls were younger ( $P < 0.05$ ) than S × A bulls at PU and PP but had similar SC. Libido scores tended ( $P < 0.10$ ) to be lower for B × A than for S × A and T × A bulls. Breed type affected ( $P < 0.05$ ) carcass traits; B × A bulls had the heaviest ( $P < 0.05$ ) hot carcass weight, greatest ( $P < 0.05$ ) dressing percentage, larger ( $P < 0.05$ ) longissimus muscle area than S × A bulls, and higher ( $P < 0.05$ ) USDA yield grade than T × A bulls but greatest ( $P < 0.05$ ) WBS force values. Breed type did not affect ( $P > 0.10$ ) USDA quality grade. In conclusion, tropically adapted F<sub>1</sub> bulls produced from Senepol (*Bos taurus*) and Tuli (Sanga) sires bred to Angus cows in Florida had lighter BW, shorter hip heights, and smaller carcasses than those from Brahman sires but reached puberty earlier and had higher libido scores and lower WBS force values.

Key Words: Bulls, Carcass Quality, Cattle Breeds, Growth, Puberty, Tropics

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## Introduction

Historically, sources of tropically adapted germplasm in the United States have been generally limited to Zebu breeds (*Bos indicus*) and, within these, primarily to the American Brahman. The Tuli is a Sanga breed

believed to have been developed from crosses between Zebu and *Bos taurus* cattle thousands of years ago in Africa, and in its environment of origin it has demonstrated high fertility and maternal performance (Oliver, 1983; Schoeman, 1989). In order to investigate the potential of Tuli in the United States, researchers organized an evaluation to be conducted in warm regions and across a number of locations representative of different climatic conditions.

Tuli- and Brahman-sired F<sub>1</sub> calves were produced in Brooksville, Florida (Chase et al., 2000), Tifton, Georgia

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<sup>3</sup>Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product to the exclusion of others that may also be suitable.

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(Baker, 1996), Clay Center, Nebraska (Cundiff et al., 1998), Las Cruces, New Mexico (Winder and Bailey, 1995), El Reno, Oklahoma, and in McGregor (Herring et al., 1996), Overton, (Browning et al., 1995), and Uvalde (Holloway et al., 1998b), Texas. Our site, at Brooksville, Florida, representative of a hot, humid, subtropical environment, also produced contemporary Senepol-sired calves. In addition to the evaluation of preweaning performance of these breed types, evaluation of postweaning performance including puberty and carcass characteristics is also critical. Most locations evaluated postweaning growth, feedlot performance, and carcass characteristics of F<sub>1</sub> steer calves (Phillips and Holloway, 1995; Baker and Williams, 1996; Herring et al., 1996; Cundiff et al., 1998). However, limited data were collected on postweaning growth and reproductive development including age at puberty in F<sub>1</sub> bull calves (Rocha et al., 1994; Cundiff et al., 1998). The objectives of the present study were to determine postweaning growth, puberty, and carcass characteristics among Brahman × Angus, Senepol × Angus, and Tuli × Angus F<sub>1</sub> bulls raised in the subtropics of Florida.

## Materials and Methods

This study was conducted at the Subtropical Agricultural Research Station (STARS; 28° 37' N latitude, 82° 22' W longitude) located near Brooksville, Florida to determine postweaning growth, puberty, and carcass characteristics for F<sub>1</sub> Brahman × Angus, Senepol × Angus, and Tuli × Angus bulls. Bull calves were born and raised at STARS and F<sub>1</sub> bull calves that were weaned in 1993 (n = 57) and 1994 (n = 53) were used in this study. A total of 31 Brahman × Angus (n = 17 and n = 14 for 1993 and 1994, respectively), 41 Senepol × Angus (n = 19 and n = 22), and 38 Tuli × Angus (n = 21 and n = 17) F<sub>1</sub> bull calves were used from 10 Brahman, 10 Senepol, and 9 Tuli sires, respectively, as described previously (Chase et al., 2000). At weaning (September 8, 1993, and September 14, 1994), calves were separated by sex and fed a preconditioning diet until the start of the study in late September (September 26, 1993, and September 27, 1994, respectively). At the start and throughout the study (until slaughter), bull calves were managed as a single group on bahiagrass (*Paspalum notatum*) pasture and were supplemented with concentrate (80% corn, 15% soybean meal, monensin, vitamins A and E, and 5% molasses) fed three times each week at a rate equivalent to 4.5 kg/d. During periods of low forage availability, bahiagrass hay was also offered free choice.

Bull calves were weighed and scrotal circumference and hip height were measured at the start of the study and at 28-d intervals for 252 d (June 6, 1994) for bulls born in 1993 and for 250 d (June 5, 1995) for bulls born in 1994. Concurrently, at 28-d intervals, when individual scrotal circumferences of a bull reached 23 cm, semen collection was attempted using an electroejaculator. Initial observations were made to determine the

presence of spermatozoa in an ejaculate. After an ejaculate showed the presence of spermatozoa, it was further evaluated immediately for the percentage of motile spermatozoa (Chenoweth et al., 1996b; Chase et al., 1997). Sperm concentration was determined using a hemocytometer. Evaluations were conducted on each bull to determine the presence of 1) first spermatozoa in an ejaculate, 2)  $50 \times 10^6$  sperm in an ejaculate with at least 10% motility, and 3)  $500 \times 10^6$  sperm in an ejaculate with at least 50% motility. After  $500 \times 10^6$  sperm with at least 50% motility were detected in an ejaculate, semen collection ceased.

After semen collection ended for all bulls, bulls were subjected to two libido tests conducted over 48 h (June 2 and 3, 1994, for bulls born in 1993 and June 1 and 2, 1995, for bulls born in 1994) as previously described (Chenoweth et al., 1996a; Chase et al., 1997). Libido scores were based on a scale of 0 (no sexual interest) to 10 (two services followed by renewed interest) as described by Chenoweth (1986a) and used at our location (Chenoweth et al., 1996a; Chase et al., 1997).

The week following the final collection of growth data (BW, hip height, and scrotal circumference), bulls were slaughtered (June 14 to 16, 1994, and June 13 and 14, 1995, for bulls born in 1993 and 1994, respectively) and processed locally at the Central Packing Co., Center Hill, FL. After hot carcass weight was recorded, carcasses were chilled at 0 to 2°C for 24 h and ribbed, and then carcass characteristics were evaluated and carcasses graded for USDA quality and yield grade factors as previously described (Chase et al., 1998). After the carcass was graded, a strip loin was removed from each carcass for bulls born in 1993 (n = 57) and from a random subset of the carcasses for bulls born in 1994 (n = 23), and each strip loin was cut into 2.54-cm steaks and trimmed of external fat in excess of 0.25 cm (if necessary), vacuum-packaged in oxygen barrier bags (Cryovac, Duncan, SC), aged for 5 d at 2°C, and then frozen at -18°C until Warner-Bratzler shear determinations were performed. Loin steaks were thawed, cooked, and Warner-Bratzler shear force determinations conducted as previously described (Chase et al., 1998).

Growth data (BW, hip height, and scrotal circumference) collected every 28 d were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included breed type, year, breed type × year, animal within breed type × year, date of sampling, breed type × date of sampling, and year × date of sampling as sources of variation. The mean square for animal within breed type × year was used as the error term to test the effects of breed type, year, and breed type × year. For presentation and interpretation of these data, the mean age of the bulls was calculated for each sampling date and data are presented in this fashion with date of sampling being equated to a mean age of all bulls on a given date of sampling averaged over years. All other data analysis conducted at a specific time or end point (i.e., initial, final, and difference in growth;

**Table 1.** Effect of breed type on initial and final growth traits of bulls for 252 d in yr 1 and 250 d in yr 2 of the study (least squares means  $\pm$  SE)

Item	Breed type		
	Brahman $\times$ Angus	Senepol $\times$ Angus	Tuli $\times$ Angus
Number of bulls	31	41	38
Age, d			
Initial	249 $\pm$ 2.6	250 $\pm$ 2.3	249 $\pm$ 2.4
Final	500 $\pm$ 2.6	501 $\pm$ 2.3	500 $\pm$ 2.4
Body weight, kg			
Initial	247 $\pm$ 4.5 <sup>b</sup>	207 $\pm$ 4.0 <sup>a</sup>	206 $\pm$ 4.2 <sup>a</sup>
Final	463 $\pm$ 8.2 <sup>b</sup>	411 $\pm$ 7.1 <sup>a</sup>	406 $\pm$ 7.5 <sup>a</sup>
Difference	216 $\pm$ 6.1	204 $\pm$ 5.3	200 $\pm$ 5.6
Hip height, cm			
Initial	114 $\pm$ 0.8 <sup>b</sup>	106 $\pm$ 0.7 <sup>a</sup>	107 $\pm$ 0.8 <sup>a</sup>
Final	131 $\pm$ 0.9 <sup>b</sup>	123 $\pm$ 0.8 <sup>a</sup>	122 $\pm$ 0.8 <sup>a</sup>
Difference	17 $\pm$ 0.8	17 $\pm$ 0.7	16 $\pm$ 0.7
Scrotal circumference, cm			
Initial	20.5 $\pm$ 0.4 <sup>a</sup>	20.8 $\pm$ 0.3 <sup>a</sup>	21.9 $\pm$ 0.3 <sup>b</sup>
Final	32.8 $\pm$ 0.4	31.5 $\pm$ 0.4	32.1 $\pm$ 0.4
Difference	12.3 $\pm$ 0.4 <sup>b</sup>	10.7 $\pm$ 0.4 <sup>a</sup>	10.2 $\pm$ 0.4 <sup>a</sup>

<sup>a,b</sup>Within a row, means without a common superscript letter differ ( $P < 0.05$ ).

presence of first spermatozoa,  $50 \times 10^6$ , and  $500 \times 10^6$  sperm per ejaculate; libido; and carcass traits) were analyzed using the GLM procedure of SAS with a model that included breed type, year, and breed type  $\times$  year as sources of variation. All data are presented as least squares means  $\pm$  SE and differences were detected using the PDIF option.

## Results

The breed type  $\times$  year interaction was not important ( $P > 0.10$ ) for age, BW, hip height, or scrotal circumference at the start (initial) or end (final) of the study; the main effects of breed type and year on these traits are summarized in Tables 1 and 2, respectively. Breed types were of similar age at the start of the study (and hence at the end of the study) when averaged over yr 1 and 2 (Table 1). However, across breed types bulls were 11 d younger ( $P < 0.001$ ) in yr 1 than in yr 2 due to year differences in date of calving and date of weaning (Table 2). Breed type affected initial ( $P < 0.001$ ) and final ( $P < 0.001$ ) BW and hip height. Brahman  $\times$  Angus bulls were heavier ( $P < 0.05$ ) and taller ( $P < 0.05$ ) at the start and end of the study than were Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls. However, breed type did not affect ( $P > 0.10$ ) the difference (final – initial) in BW and hip height observed during the study. There was no effect ( $P > 0.10$ ) of year on initial BW or hip height, but year affected final BW ( $P < 0.001$ ) and hip height ( $P < 0.001$ ); bulls were 33 kg heavier and 4.3 cm taller at the end of the study in yr 2 than in yr 1 (Table 2). This is consistent with the greater gains (difference) in BW ( $P < 0.001$ ) and hip height ( $P < 0.001$ ) that were observed in yr 2 compared with yr 1.

Breed type affected ( $P < 0.01$ ) initial scrotal circumference and tended ( $P < 0.10$ ) to affect final scrotal

circumference. At the start of the study, Tuli  $\times$  Angus bulls had a larger ( $P < 0.05$ ) scrotal circumference than Brahman  $\times$  Angus and Senepol  $\times$  Angus bulls. At the end of the study, however, no difference ( $P > 0.05$ ) in scrotal circumference was observed among breed types. Brahman  $\times$  Angus bulls had greater ( $P < 0.05$ ) growth (difference) in scrotal circumference (12.3 cm) during the study than Senepol  $\times$  Angus (10.7 cm) and Tuli  $\times$  Angus bulls (10.2 cm). Year affected initial ( $P < 0.001$ ) and final ( $P < 0.05$ ) scrotal circumference; larger initial and final scrotal circumferences for bulls were recorded in yr 2 than in yr 1 of the study. However, year did not

**Table 2.** Effect of year on initial and final growth traits of Brahman  $\times$  Angus, Senepol  $\times$  Angus, and Tuli  $\times$  Angus bulls (least squares means  $\pm$  SE)

Item <sup>a</sup>	Year	
	1	2
Number of bulls	57	53
Age, d		
Initial***	244 $\pm$ 2.0	255 $\pm$ 2.1
Final***	496 $\pm$ 2.0	505 $\pm$ 2.1
Body weight, kg		
Initial	220 $\pm$ 3.4	221 $\pm$ 3.5
Final***	410 $\pm$ 6.0	443 $\pm$ 6.4
Difference***	191 $\pm$ 4.5	222 $\pm$ 4.7
Hip height, cm		
Initial	109 $\pm$ 0.6	109 $\pm$ 0.6
Final***	123 $\pm$ 0.7	128 $\pm$ 0.7
Difference***	14 $\pm$ 0.6	19 $\pm$ 0.6
Scrotal circumference, cm		
Initial***	20.3 $\pm$ 0.3	21.8 $\pm$ 0.3
Final*	31.6 $\pm$ 0.3	32.6 $\pm$ 0.3
Difference	11.3 $\pm$ 0.3	10.8 $\pm$ 0.3

<sup>a</sup>Effect of year: \*\*\* $P < 0.001$ ; \*\* $P < 0.01$ ; \* $P < 0.05$ ; † $P < 0.10$ .

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affect ( $P > 0.10$ ) overall growth (difference) in scrotal circumference observed during the study.

From the analyses of growth data collected at 28-d intervals and sampling date equated to the mean age of the bulls at each sampling date, the effect of breed type and age on BW, hip height, and scrotal circumference averaged over the 2 yr are shown in Figure 1. For both BW and hip height, the breed type  $\times$  year interaction was not an important ( $P > 0.10$ ) source of variation, whereas breed type ( $P < 0.001$ ), year ( $P < 0.05$ ), age ( $P < 0.001$ ), and year  $\times$  age ( $P < 0.001$ ) were important for BW and hip height. The breed type  $\times$  age interaction was important for BW ( $P < 0.05$ ) but not for hip height ( $P > 0.10$ ). Brahman  $\times$  Angus bulls were consistently heavier and taller than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls throughout the study (Figure 1). However, BW and hip height were similar between Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls.

The breed type  $\times$  year interaction was not important ( $P > 0.10$ ) for scrotal circumference (Figure 1c), but breed type ( $P < 0.10$ ), year ( $P < 0.05$ ), age ( $P < 0.001$ ), breed type  $\times$  age ( $P < 0.001$ ), and year  $\times$  age ( $P < 0.001$ ) were important sources of variation. In general, Tuli  $\times$  Angus bulls had larger scrotal circumference than Brahman  $\times$  Angus and Senepol  $\times$  Angus bulls from 246 to 389 d of age, but scrotal circumference seemed to be similar among breed types thereafter up to 500 d of age. The scrotal circumference of Brahman  $\times$  Angus bulls was numerically the largest at 500 d.

At the presence of first spermatozoa in an ejaculate, breed type affected age ( $P < 0.001$ ), BW ( $P < 0.001$ ), hip height ( $P < 0.001$ ), and scrotal circumference ( $P < 0.05$ ). Brahman  $\times$  Angus bulls were older ( $P < 0.05$ ), heavier ( $P < 0.05$ ), and taller ( $P < 0.05$ ) than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls at the time of presence of first spermatozoa in an ejaculate (Table 3). Brahman  $\times$  Angus bulls had a smaller scrotal circumference than Senepol  $\times$  Angus but a scrotal circumference similar to that of Tuli  $\times$  Angus at presence of first spermatozoa in an ejaculate. Year did not affect ( $P > 0.10$ ) any traits at presence of first spermatozoa in an ejaculate; however, breed type  $\times$  year was important ( $P < 0.05$ ) for scrotal circumference and tended to be important for BW ( $P < 0.10$ ) and hip height ( $P < 0.10$ ), but not age ( $P > 0.10$ ). This was due to a larger scrotal circumference observed at presence of first spermatozoa in an ejaculate in yr 2 than in yr 1 from Brahman  $\times$  Angus (25.1 vs 26.4 cm for yr 1 vs 2, respectively) but not from Tuli  $\times$  Angus (25.4 vs 24.7 cm) or Senepol  $\times$  Angus (24.4 vs 24.8 cm) bulls. Heavier BW and taller hip heights were observed in yr 2 than in yr 1 in Brahman  $\times$  Angus (311 vs 329 kg and 119.5 vs 121.7 kg for yr 1 vs 2, respectively) and Senepol  $\times$  Angus (247 vs 268 kg and 110.6 vs 112.8 cm) but not in Tuli  $\times$  Angus (249 vs 239 kg and 111.0 vs 108.6 cm) bulls.

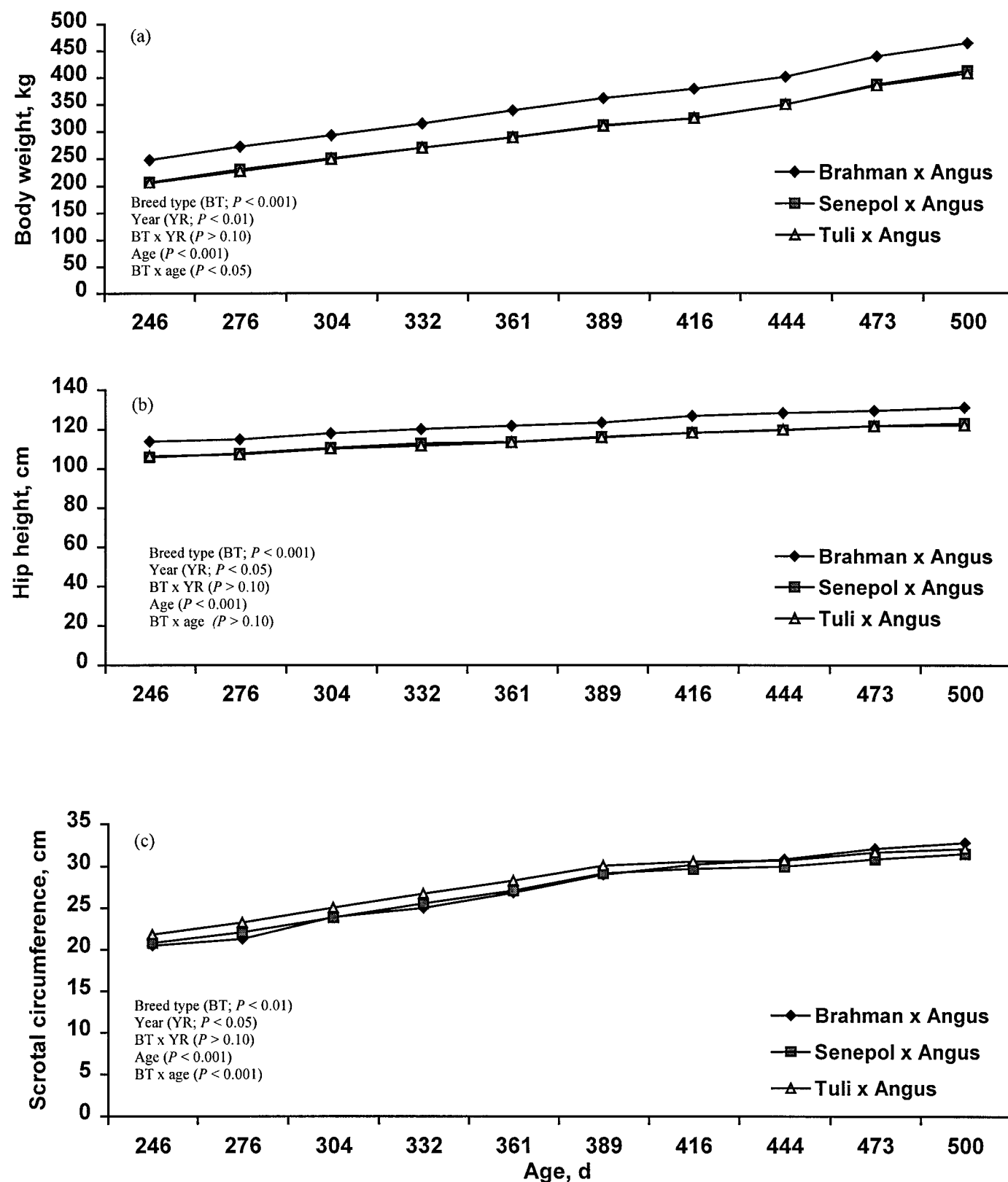
The breed type  $\times$  year interaction was not important for any traits measured at  $50 \times 10^6$  sperm per ejaculate with at least 10% motility ( $50 \times 10^6$  sperm per ejaculate) or at  $500 \times 10^6$  sperm per ejaculate with at least 50%

motility ( $500 \times 10^6$  sperm per ejaculate). Breed type affected all traits measured at  $50 \times 10^6$  ( $P < 0.001$ ) and  $500 \times 10^6$  ( $P < 0.001$  except scrotal circumference =  $P < 0.01$ ) sperm per ejaculate. At both  $50 \times 10^6$  and  $500 \times 10^6$  sperm per ejaculate, Brahman  $\times$  Angus bulls were older ( $P < 0.05$ ), heavier ( $P < 0.05$ ), and taller ( $P < 0.05$ ) and had larger scrotal circumference ( $P < 0.05$ ) than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls (Table 3). At  $50 \times 10^6$  sperm per ejaculate, Senepol  $\times$  Angus bulls were 26 d older ( $P < 0.05$ ) and 21 kg heavier ( $P < 0.05$ ) than Tuli  $\times$  Angus bulls but had similar hip height and scrotal circumference. At  $500 \times 10^6$  sperm per ejaculate, Senepol  $\times$  Angus bulls were 23 d older ( $P < 0.05$ ) and 2.6 cm taller ( $P < 0.05$ ) than Tuli  $\times$  Angus bulls but did not differ in BW and scrotal circumference. Year of study tended ( $P < 0.10$ ) to affect age of bulls and did affect ( $P < 0.05$  to  $P < 0.001$ ) BW, hip height, and scrotal circumference at both  $50 \times 10^6$  and  $500 \times 10^6$  sperm per ejaculate (Table 4).

Libido test results were analyzed over the 2-yr study using data collected for 10 min on two consecutive days each year (Figure 2). Neither libido score nor the number of services was influenced ( $P > 0.10$ ) by year or the breed type  $\times$  year interaction. Breed type tended to affect average ( $P < 0.10$ ) and maximum ( $P < 0.10$ ) libido scores and average ( $P = 0.10$ ) and maximum ( $P = 0.12$ ) number of services that were observed. Brahman  $\times$  Angus bulls tended to have lower libido scores and fewer numbers of services than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls.

Breed type affected hot carcass weight ( $P < 0.001$ ), dressing percentage ( $P < 0.01$ ), fat thickness ( $P < 0.01$ ), longissimus muscle area ( $P < 0.01$ ), kidney, pelvic, and heart fat ( $P < 0.05$ ), USDA yield grade ( $P < 0.05$ ), lean color ( $P < 0.10$ ), lean firmness ( $P < 0.05$ ), and Warner-Bratzler shear force values ( $P < 0.01$ ; Table 5). Year of the study affected most carcass traits, and greater values were observed in yr 2 than in yr 1, except for lean maturity, overall maturity, and lean scores (Table 6). This was expected because bulls were heavier and taller in yr 2 than in yr 1 (Table 2). The breed type  $\times$  year interaction was not important ( $P > 0.10$ ) for most carcass traits except lean firmness ( $P < 0.05$ ) and Warner-Bratzler shear force ( $P < 0.10$ ).

Hot carcass weights and dressing percentages were greater ( $P < 0.05$ ) for Brahman  $\times$  Angus bulls than for Senepol  $\times$  Angus or Tuli  $\times$  Angus bulls (Table 5). Brahman  $\times$  Angus and Tuli  $\times$  Angus bulls had similar adjusted fat thickness and kidney, pelvic, and heart fat, which were greater ( $P < 0.05$ ) than those from Senepol  $\times$  Angus bulls. Longissimus muscle area was larger ( $P < 0.05$ ) for Brahman  $\times$  Angus than for Senepol  $\times$  Angus, and the Tuli  $\times$  Angus bulls were intermediate but not significantly different from the other breed types. Brahman  $\times$  Angus bulls had higher ( $P < 0.05$ ) USDA yield grades than Tuli  $\times$  Angus bulls, but USDA yield grades of Senepol  $\times$  Angus bulls did not differ from those of either of the other breed types. Breed type did not affect ( $P > 0.10$ ) USDA quality grade, which averaged near



**Figure 1.** Effect of breed type on body weight (panel a; SEM = 6.0, 5.2, and 5.5 kg for Brahman  $\times$  Angus [B  $\times$  A], Senepol  $\times$  Angus [S  $\times$  A], and Tuli  $\times$  Angus [T  $\times$  A], respectively), hip height (panel b; SEM = 0.8 cm for B  $\times$  A and 0.7 cm for S  $\times$  A and T  $\times$  A), and scrotal circumference (panel c; SEM = 0.4 cm for all breed types) from 246 to 500 days of age.

**Table 3.** Effect of breed type on age and growth traits of bulls at presence of first spermatozoa in an ejaculate,  $50 \times 10^6$  sperm per ejaculate with at least 10% motility, and  $500 \times 10^6$  sperm per ejaculate with at least 50% motility in a 2-yr study (least squares means  $\pm$  SE)

Item	Breed type		
	Brahman $\times$ Angus	Senepol $\times$ Angus	Tuli $\times$ Angus
Number of bulls	31	41	38
First spermatozoa			
Age, d	342 $\pm$ 7.5 <sup>b</sup>	319 $\pm$ 6.5 <sup>a</sup>	302 $\pm$ 7.0 <sup>a</sup>
Body weight, kg	320 $\pm$ 5.6 <sup>b</sup>	257 $\pm$ 4.8 <sup>a</sup>	244 $\pm$ 5.1 <sup>a</sup>
Hip height, cm	121 $\pm$ 0.8 <sup>b</sup>	112 $\pm$ 0.7 <sup>a</sup>	110 $\pm$ 0.8 <sup>a</sup>
Scrotal circumference, cm	25.7 $\pm$ 0.3 <sup>b</sup>	24.6 $\pm$ 0.2 <sup>a</sup>	25.1 $\pm$ 0.3 <sup>a,b</sup>
$50 \times 10^6$ sperm			
Age, d	392 $\pm$ 8.3 <sup>c</sup>	356 $\pm$ 7.2 <sup>b</sup>	330 $\pm$ 7.9 <sup>a</sup>
Body weight, kg	361 $\pm$ 6.9 <sup>c</sup>	285 $\pm$ 6.0 <sup>b</sup>	266 $\pm$ 6.5 <sup>a</sup>
Hip height, cm	124 $\pm$ 0.8 <sup>b</sup>	114 $\pm$ 0.7 <sup>a</sup>	112 $\pm$ 0.8 <sup>a</sup>
Scrotal circumference, cm	28.8 $\pm$ 0.4 <sup>b</sup>	26.8 $\pm$ 0.4 <sup>a</sup>	27.0 $\pm$ 0.4 <sup>a</sup>
$500 \times 10^6$ sperm			
Age, d	434 $\pm$ 7.6 <sup>c</sup>	405 $\pm$ 6.7 <sup>b</sup>	382 $\pm$ 7.2 <sup>a</sup>
Body weight, kg	398 $\pm$ 7.8 <sup>b</sup>	319 $\pm$ 7.2 <sup>a</sup>	304 $\pm$ 7.8 <sup>a</sup>
Hip height, cm	127 $\pm$ 0.9 <sup>c</sup>	118 $\pm$ 0.8 <sup>b</sup>	116 $\pm$ 0.9 <sup>a</sup>
Scrotal circumference, cm	30.7 $\pm$ 0.4 <sup>b</sup>	29.0 $\pm$ 0.3 <sup>a</sup>	29.3 $\pm$ 0.4 <sup>a</sup>

<sup>a,b,c</sup>Within a row, means without a common superscript letter differ ( $P < 0.05$ ).

the middle of the USDA Standard grade for these bulls. Warner-Bratzler shear force was greater ( $P < 0.05$ ) for Brahman  $\times$  Angus than for Senepol  $\times$  Angus or Tuli  $\times$  Angus bulls. The trend ( $P < 0.10$ ) for the breed type  $\times$  year interaction for Warner-Bratzler shear force was

due to an increase observed from yr 1 to yr 2 in Brahman  $\times$  Angus (6.0 vs 7.4 kg for yr 1 vs yr 2, respectively) and Tuli  $\times$  Angus (4.9 vs 6.4 kg) bulls but not in Senepol  $\times$  Angus (5.4 vs 5.0 kg) bulls.

## Discussion

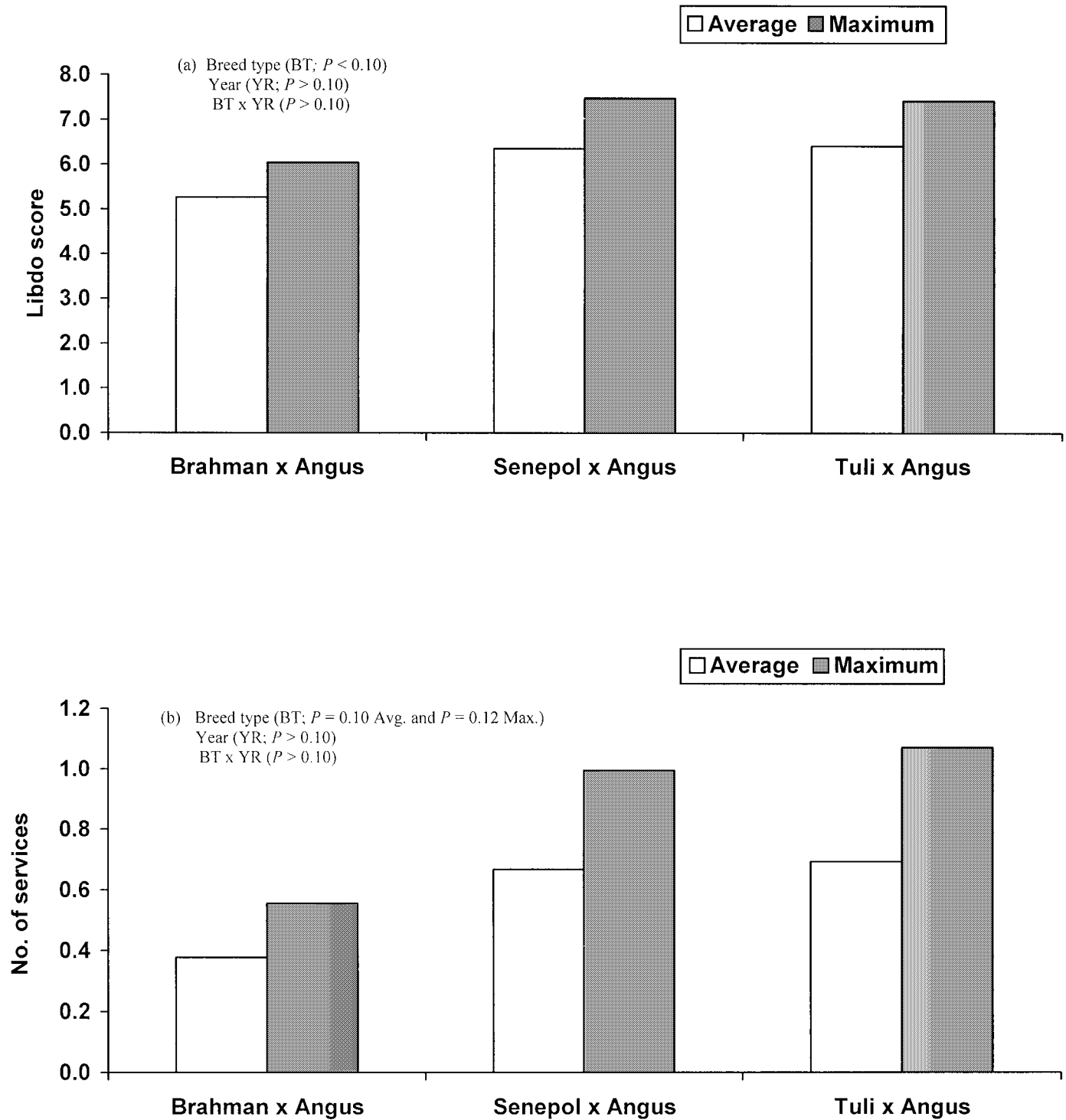
**Table 4.** Effect of year on age and growth traits of Brahman  $\times$  Angus, Senepol  $\times$  Angus, and Tuli  $\times$  Angus bulls at presence of first spermatozoa in an ejaculate,  $50 \times 10^6$  sperm per ejaculate with at least 10% motility, and  $500 \times 10^6$  sperm per ejaculate with at least 50% motility (least squares means  $\pm$  SE)

Item <sup>a</sup>	Year	
	1	2
Number of bulls	57	53
First spermatozoa		
Age, d	320 $\pm$ 5.6	322 $\pm$ 5.9
Body weight, kg	269 $\pm$ 4.1	279 $\pm$ 4.3
Hip height, cm	114 $\pm$ 0.6	114 $\pm$ 0.6
Scrotal circumference, cm	25.0 $\pm$ 0.2	25.3 $\pm$ 0.2
$50 \times 10^6$ sperm		
Age <sup>†</sup> , d	351 $\pm$ 6.1	367 $\pm$ 6.6
Body weight <sup>**</sup> , kg	293 $\pm$ 5.1	315 $\pm$ 5.5
Hip height <sup>*</sup> , cm	115 $\pm$ 0.6	118 $\pm$ 0.7
Scrotal circumference <sup>***</sup> , cm	26.8 $\pm$ 0.3	28.3 $\pm$ 0.3
$500 \times 10^6$ sperm		
Age <sup>†</sup> , d	399 $\pm$ 5.6	415 $\pm$ 6.1
Body weight <sup>***</sup> , kg	323 $\pm$ 6.0	357 $\pm$ 6.6
Hip height <sup>**</sup> , cm	119 $\pm$ 0.7	122 $\pm$ 0.8
Scrotal circumference <sup>***</sup> , cm	29.0 $\pm$ 0.3	30.4 $\pm$ 0.3

<sup>a</sup>Effect of year: \*\*\* $P < 0.001$ ; \*\* $P < 0.01$ ; \* $P < 0.05$ ; <sup>†</sup> $P < 0.10$ .

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Results of the present study indicated that Brahman  $\times$  Angus bulls were heavier and taller after weaning than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls but that postweaning growth rates for these traits were similar among the breed types. Heavier BW and taller hip heights at weaning for Brahman-sired calves than for Tuli-sired calves (Baker, 1996; Herring et al., 1996; Cundiff et al., 1998) and Senepol-sired calves (Holloway et al., 1998b; Chase et al., 2000) have previously been reported and are in agreement with the initial growth measurements reported in this study. Limited postweaning growth data of F<sub>1</sub> bulls of breed types similar to those used in the present study have been published. In agreement with the present study, Tuli-sired F<sub>1</sub> bull calves had lighter BW than Brahman-sired F<sub>1</sub> bull calves but similar ADG from approximately 250 to 500 d of age at Clay Center, Nebraska (Lunstra and Cundiff, unpublished data). Tuli  $\times$  Angus bulls were reported to have lighter BW on test than Angus  $\times$  Brahman bulls but similar ADG during a 77-d postweaning test in Texas (Rocha et al., 1994). A number of reports indicated heavier initial and final BW for Brahman-sired steers than for Tuli- (Baker and Williams, 1996; Herring et al., 1996; Cundiff et al., 1998) and Senepol-sired (Phillips and Holloway, 1995) steers in backgrounding/finishing studies. In some of those studies, breed type differences were also reported in ADG.



**Figure 2.** Effect of breed type on libido score (panel a; average over two days [SEM = 0.4 for all breed types] and maximum [SEM = 0.5 for all breed types]) and number of services (panel b; average over two days [SEM = 0.1 for all breed types] and maximum [SEM = 0.2 for all breed types]) within 10 minutes. Libido score scale: 5 = Two mounts or mounting attempts, with no service, 6 = More than two mounts or mounting attempts with no service, 7 = One service followed by no further sexual interest, 8 = One service followed by sexual interest, including mounts or mounting attempts.

In contrast to BW and skeletal growth, Tuli  $\times$  Angus bulls initially had larger scrotal circumference than Brahman  $\times$  Angus and Senepol  $\times$  Angus bulls until approximately 389 d of age. Thereafter, scrotal circum-

ference was similar among breed types. Final scrotal circumference of Brahman  $\times$  Angus bulls was numerically the largest, resulting in greater gains in scrotal circumference for Brahman  $\times$  Angus bulls than for the



other breed types. In agreement with these results, scrotal circumferences of Tuli-sired vs Brahman-sired F<sub>1</sub> bulls at Clay Center, Nebraska, were reported to be larger for Tuli-sired bulls at 8 mo of age, similar at 12 mo of age, and larger for Brahman-sired bulls at 16 mo of age (Cundiff et al., 1998). However, in Uvalde, Texas, paired testes weights were reported to be larger for Senepol × Angus bulls than for Brahman × Angus bulls and intermediate for Tuli × Angus bulls, which did not differ from either of the other breed types (Browning et al., 1997). Although scrotal circumference was not reported in that study, heavier testes weights, particularly at weaning, could be indicative of larger scrotal circumference.

Tuli × Angus and Senepol × Angus bulls reached first sperm,  $50 \times 10^6$  sperm, and  $500 \times 10^6$  sperm per ejaculate at younger ages, lighter body weights, and shorter hip heights than Brahman × Angus bulls. Tuli × Angus bulls reached  $50 \times 10^6$  and  $500 \times 10^6$  sperm per ejaculate about 30 d sooner than Senepol × Angus bulls, and at each of these times scrotal circumference was smaller in Tuli × Angus and Senepol × Angus bulls than in Brahman × Angus bulls. In agreement with the present study, Cundiff et al. (1998) reported in Nebraska that Tuli-sired F<sub>1</sub> bulls reached  $500 \times 10^6$  sperm per ejaculate at a younger age, lighter body weight, and smaller scrotal circumference than Brahman × Angus bulls.

Likewise, in Texas, when Tuli × Angus bulls were compared to Angus × Brahman bulls, Tuli × Angus bulls had lighter BW at first sperm,  $50 \times 10^6$ , and  $500 \times 10^6$  sperm per ejaculate and were younger and had somewhat smaller scrotal circumference at first sperm and  $50 \times 10^6$  sperm per ejaculate (Rocha et al., 1994).

Libido scores and number of services tended to be greater for Tuli × Angus and Senepol × Angus bulls than Brahman × Angus bulls. Previously we reported that purebred temperate-adapted *Bos taurus* bulls (Angus and Hereford) had higher libido scores than *Bos indicus* bulls (Brahman) and that libido scores of tropically adapted *Bos taurus* bulls (Senepol and Romosinuano) were intermediate (Chenoweth et al., 1996a; Chase et al., 1997). Results from other studies also support these observations (Perry et al., 1991; Chase et al., 1993) and suggest that crossbreds have greater libido scores than purebreds (Chenoweth, 1986b). Because all bulls were crossbreds in the current study we cannot directly address that point. Furthermore, we cannot rule out the possibility that the testing procedure did not influence the results, because purebred Brahman perform poorly under similar libido test conditions (Chenoweth et al., 1996a). However, in the present study Brahman × Angus bulls did display much higher libido scores and number of services than was reported for purebred Brahman in previous studies.

**Table 5.** Effect of breed type on carcass characteristics of bulls in a 2-yr study (least squares means ± SE)

Item	Breed type		
	Brahman × Angus	Senepol × Angus	Tuli × Angus
Number of bulls	31	41	38
Age, d	509 ± 2.6	510 ± 2.3	509 ± 2.4
Hot carcass weight, kg	271 ± 5.0 <sup>b</sup>	225 ± 4.3 <sup>a</sup>	225 ± 4.5 <sup>a</sup>
Dressing percentage	55.1 ± 0.6 <sup>b</sup>	52.8 ± 0.5 <sup>a</sup>	52.7 ± 0.5 <sup>a</sup>
Fat thickness, mm	2.9 ± 0.3 <sup>b</sup>	1.6 ± 0.2 <sup>a</sup>	2.3 ± 0.2 <sup>a,b</sup>
Adjusted fat thickness, mm	2.6 ± 0.2 <sup>b</sup>	1.5 ± 0.2 <sup>a</sup>	2.2 ± 0.2 <sup>b</sup>
Longissimus muscle, cm <sup>2</sup>	79.3 ± 1.6 <sup>b</sup>	72.2 ± 1.4 <sup>a</sup>	76.1 ± 1.4 <sup>a,b</sup>
Kidney, pelvic, and heart fat, %	0.92 ± 0.06 <sup>b</sup>	0.76 ± 0.05 <sup>a</sup>	0.98 ± 0.06 <sup>b</sup>
USDA yield grade	1.30 ± 0.07 <sup>b</sup>	1.12 ± 0.06 <sup>a,b</sup>	1.06 ± 0.06 <sup>a</sup>
Marbling score <sup>c</sup>	177 ± 11.1	184 ± 9.7	193 ± 10.0
Lean maturity <sup>d</sup>	181 ± 5.0	191 ± 4.3	190 ± 4.5
Bone maturity <sup>d</sup>	166 ± 1.7	166 ± 1.5	165 ± 1.5
Overall maturity <sup>d</sup>	174 ± 2.5	179 ± 2.2	177 ± 2.3
USDA quality grade <sup>e</sup>	439 ± 5.7	441 ± 4.9	448 ± 5.2
Lean color score <sup>f</sup>	3.2 ± 0.2 <sup>x</sup>	3.8 ± 0.2 <sup>y</sup>	3.8 ± 0.2 <sup>y</sup>
Lean texture score <sup>g</sup>	3.1 ± 0.1	3.2 ± 0.1	3.1 ± 0.1
Lean firmness score <sup>h</sup>	2.8 ± 0.1 <sup>a</sup>	3.2 ± 0.1 <sup>b</sup>	2.8 ± 0.1 <sup>a</sup>
Fat color score <sup>i</sup>	2 ± 0	2 ± 0	2 ± 0
Number of bulls	22	30	28
Warner-Bratzler shear, kg	6.7 ± 0.4 <sup>b</sup>	5.2 ± 0.3 <sup>a</sup>	5.6 ± 0.3 <sup>a</sup>

<sup>a,b</sup>Within a row, means without a common superscript letter differ ( $P < 0.05$ ).

<sup>c</sup>100 = practically devoid, 200 = traces.

<sup>d</sup>100 = A, 200 = B.

<sup>e</sup>400 = Standard, 500 = Select.

<sup>f</sup>Scored on an 8-point scale (3 = light cherry red, 4 = slightly light cherry red).

<sup>g</sup>Scored on a 7-point scale (3 = moderately fine, 4 = slightly coarse).

<sup>h</sup>Scored on a 7-point scale (2 = firm, 3 = moderately firm, 4 = slightly soft).

<sup>i</sup>Scored on a 4-point scale (2 = cream).

<sup>x,y</sup>Within a row, means without a common superscript letter differ ( $P < 0.10$ ).

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**Table 6.** Effect of year on carcass characteristics of Brahman  $\times$  Angus, Senepol  $\times$  Angus, and Tuli  $\times$  Angus bulls (least squares means  $\pm$  SE)

Item <sup>a</sup>	Year	
	1	2
Number of bulls	57	53
Age, d	505 $\pm$ 2.0	514 $\pm$ 2.1
Hot carcass weight*, kg	234 $\pm$ 3.7	247 $\pm$ 3.9
Dressing percentage*	52.9 $\pm$ 0.4	54.2 $\pm$ 0.4
Fat thickness, mm	2.2 $\pm$ 0.2	2.4 $\pm$ 0.2
Adjusted fat thickness***, mm	1.3 $\pm$ 0.2	2.8 $\pm$ 0.2
Longissimus muscle, cm <sup>2</sup>	75.5 $\pm$ 1.2	76.1 $\pm$ 1.2
Kidney, pelvic, heart fat***, %	0.67 $\pm$ 0.05	1.10 $\pm$ 0.05
USDA yield grade***	1.0 $\pm$ 0.1	1.3 $\pm$ 0.1
Marbling score* <sup>b</sup>	170 $\pm$ 8.3	201 $\pm$ 8.5
Lean maturity*** <sup>c</sup>	205 $\pm$ 3.7	169 $\pm$ 3.9
Bone maturity*** <sup>c</sup>	158 $\pm$ 1.2	173 $\pm$ 1.3
Overall maturity*** <sup>c</sup>	182 $\pm$ 1.8	171 $\pm$ 1.9
USDA quality grade*** <sup>d</sup>	434 $\pm$ 4.2	451 $\pm$ 4.4
Lean color score* <sup>e</sup>	3.8 $\pm$ 0.1	3.3 $\pm$ 0.2
Lean texture score** <sup>f</sup>	3.3 $\pm$ 0.1	3.0 $\pm$ 0.1
Lean firmness score*** <sup>g</sup>	3.1 $\pm$ 0.1	2.7 $\pm$ 0.1
Fat color score <sup>h</sup>	2 $\pm$ 0	2 $\pm$ 0
Number of bulls	57	23
Warner-Bratzler shear*, kg	5.4 $\pm$ 0.2	6.3 $\pm$ 0.3

<sup>a</sup>Effect of year: \*\*\* $P < 0.001$ ; \*\* $P < 0.01$ ; and \* $P < 0.05$ .

<sup>b</sup>100 = practically devoid, 200 = traces, 300 = slight.

<sup>c</sup>100 = A, 200 = B, 300 = C.

<sup>d</sup>400 = Standard, 500 = Select.

<sup>e</sup>Scored on an 8-point scale (3 = light cherry red, 4 = slightly light cherry red).

<sup>f</sup>Scored on a 7-point scale (3 = moderately fine, 4 = slightly coarse).

<sup>g</sup>Scored on a 7-point scale (2 = firm, 3 = moderately firm, 4 = slightly soft).

<sup>h</sup>Scored on a 4-point scale (2 = cream).

As expected from live weights, hot carcass weights were heavier for Brahman  $\times$  Angus bulls than for Tuli  $\times$  Angus and Senepol  $\times$  Angus bulls. Similar effects of sire breed have been reported among Brahman-, Tuli- (Herring et al., 1996; Cundiff et al., 1998) and Senepol-sired (Phillips and Holloway, 1995) steers. Brahman  $\times$  Angus bulls had greater longissimus muscle area than Senepol  $\times$  Angus bulls but were similar to Tuli  $\times$  Angus bulls in the present study. Others reported no difference in longissimus muscle area among Brahman-, Tuli-, (Herring et al., 1996; Cundiff et al., 1998) and Senepol-sired (Holloway et al., 1998a) steers. There was no difference among breed types in marbling score and USDA quality grade in the present study. Others have reported higher marbling score (Herring et al., 1996; Cundiff et al., 1998) and greater percentage of carcasses grading USDA Choice (Baker and Williams, 1996; Cundiff et al., 1998) for Tuli-sired than for Brahman-sired steers. Holloway et al. (1998a) reported that Senepol  $\times$  Angus and Tuli  $\times$  Angus steers had higher marbling scores than Brahman  $\times$  Angus steers.

Warner-Bratzler shear force was greater for Brahman  $\times$  Angus bulls than for Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls. Herring et al. (1996) reported no difference in shear force between Brahman- and Tuli-sired steers, whereas Cundiff et al. (1998) reported greater

shear force for Brahman- than for Tuli-sired steers. Previous data collected at our location suggested that carcasses from Senepol  $\times$  Angus steers were about one-third of a USDA quality grade higher and Warner-Bratzler shear force values slightly lower than those from Brahman  $\times$  Angus steers (Butts, 1987). We have also reported similar Warner-Bratzler shear force values between Senepol and Hereford steers (Chase et al., 1998). Comparison of the carcass traits in the present study with other studies is difficult because the other studies were conducted with steers fed feedlot diets, whereas bulls were fed a developing diet in our study. However, carcass traits obtained in the current study may have application in tropical regions of the world where bulls rather than steers are finished on pasture.

In conclusion, results from this study conducted in the subtropics of central Florida indicate that Brahman  $\times$  Angus bulls had heavier postweaning BW, taller hip heights, heavier carcasses, and greater dressing percentages but reached puberty at older ages, had lower libido scores, and higher Warner-Bratzler shear force values than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls. Postweaning performance and puberty reported among the breed types in this study seemed to agree with results from other U.S. locations and environments, although data on bulls are limited. There was less agreement between the results of carcass data reported in the present study and other studies, most likely because the present study was conducted using bulls fed a developing supplement on pasture whereas steers were fed feedlot diets in the other studies.

## Implications

Postweaning growth, reproductive development, and carcass characteristics differed among tropically adapted F<sub>1</sub> bulls produced and raised in central Florida. Brahman  $\times$  Angus bulls were larger and had heavier carcasses and greater dressing percentages than Senepol  $\times$  Angus and Tuli  $\times$  Angus bulls, but they reached puberty later and their carcasses had higher Warner-Bratzler shear force values. These observations are in general agreement with those for similar breeds of sires reported across other locations and environments in the United States and should be of value to beef cattle producers who raise or purchase bulls. Carcass data from these bulls fed a developing supplement on pasture may be applicable to tropical regions of the world where bulls rather than steers are commonly marketed for meat production.

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